

60 Mendel, First Geneticist



In Activity 59, “Gene Combo,” you investigated a model for how inheritance works. This model is based on the work of Gregor Mendel. He discovered the behavior of genes 40 years before scientists learned where genes are located in the cell and almost 100 years before scientists discovered what the genes are made of!



Who was Gregor Mendel, and how did he discover the basis of heredity by breeding pea plants?

READING

Part A: Mendel’s Life



In 1865 an Austrian monk named Gregor Mendel published his work on the behavior of genes. Mendel lived in a monastery that was devoted to teaching and science, as well as religious matters. Mendel had prepared to be a science teacher and had studied math, botany, and plant breeding for several years. The monastery had an experimental garden for agricultural research. Research then, as now, included breeding varieties of plants and animals in order to produce superior food and other products. Mendel became interested in the pea plants he was working on. He wondered how the colors, shapes, and heights of offspring pea plants were related to those of the parent plants. He began a careful study of how characteristics are inherited in pea plants. Mendel’s discoveries depended upon research about breeding plants, careful experiments, and creative thinking. He understood that plant seeds are produced by sexual reproduction. He also understood the mathematics of probability.

His experiments were planned so carefully and recorded so thoroughly that anyone could repeat his procedure and confirm his findings. The patterns he discovered apply to all sexually reproducing organisms, from petunias to peas, from earthworms to humans. His discoveries have helped people answer questions ranging from how to produce disease-resistant food crops to explaining human diseases such as cystic fibrosis and sickle-cell disease.





STOPPING TO THINK 1

What personal qualities do you think Mendel must have had that helped him in his work?

Part B: Mendel's Experiments with Pea Plants

Plants in general, and pea plants in particular, were excellent organisms for Mendel to study, for the following reasons:

- They grow into mature plants very quickly; in about 60–80 days their seeds grow and develop into mature plants.
- They produce numerous seeds rapidly.
- They have many observable characteristics that come in just two alternatives (such as purple or white flowers, yellow or green pods), with no blending of these traits (no lavender flowers, no yellowish green pods).

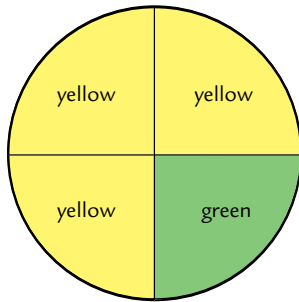
Mendel's Results				
	Flower color 	Seed color 	Seed surface 	Pod color 
Original cross (generation one)	purple x white	green x yellow	wrinkled x smooth	green x yellow
Generation two offspring	all purple	all yellow	all smooth	all green
Generation three offspring	705 : 224 (purple:white)	6,022 : 2,001 (yellow:green)	5,474 : 1,850 (smooth:wrinkled)	428 : 152 (green:yellow)

Mendel decided to breed extremely large numbers of pea plants and search for simple patterns in the offspring. The table above shows the results he obtained for four of the characteristics he studied.

Notice that Mendel did hundreds of crosses, and observed and counted the offsprings' traits for thousands of pea seeds, pods, and flowers. He then analyzed all these results and applied his knowledge of statistics and probability to infer the behavior of individual genes.

STOPPING TO THINK 2

- What were the advantages for Mendel in using pea plants for his breeding investigations?
- Why did Mendel perform so many crosses for the same characteristics?



SEED COLOR RATIOS

As he looked at the data, Mendel noticed an interesting relationship. If he calculated the ratio of the two traits in the third generation, he obtained a ratio very near to 3:1.

For example, for seed color the ratio of yellow to green seeds can be calculated as

$$\frac{6,022 \text{ yellow}}{2,001 \text{ green}} = \frac{3.01 \text{ yellow}}{1 \text{ green}}$$

This is almost exactly a 3:1 ratio of yellow:green. This means that for every 1 green-seeded plant, there were almost exactly 3 yellow-seeded plants in the third generation.

You can also express this in terms of the fractions $\frac{3}{4}$ yellow and $\frac{1}{4}$ green, as shown in the pie graph at left.

Mendel concluded that not only did the green-seeded trait reappear in the third generation, but the probability of a third-generation plant having that trait was $\frac{1}{4}$ —that is, about one green-seeded plant for every four plants produced overall.

He found the same ratio with other characteristics also. The 3:1 ratio he found for all of these different characteristics was the clue to how the parents' genes combine in their offspring. Based on his analysis, he proposed that:

- Each trait that appears in the second generation is the dominant version of the characteristic. The trait that is “hidden” is called **recessive**.
- Every plant has two copies of the gene for each characteristic. These two copies are called **alleles**. (The evidence suggested there was more than one copy of the gene for each characteristic in each plant, so the simplest assumption that would work was to have two alleles, or copies, per characteristic.)
- Each pea plant receives only one allele for each characteristic from each parent and ends up with two alleles of its own.

He then used these ideas to argue that the 3:1 ratio is exactly what is expected in the third generation for every plant characteristic. In the last two activities, you have explored this proposal, using disks and coins as models for genes.

STOPPING TO THINK 3

Explain how the model in Activity 59, “Gene Combo,” works exactly like Mendel’s explanation for his results with pea plants.

Activity 60 • Mendel, First Geneticist

Mendel published his results in a paper that was mostly ignored at the time. Scientists and breeders failed to understand what he had done. Never before had someone used mathematics to tackle a complex biological problem. Mendel's work was rediscovered and understood only after scientists realized that genes must be located on the chromosomes found in the nucleus of the cell. You will learn about chromosomes in Activity 63, "Show Me the Genes!"

ANALYSIS

1. Based on Mendel's results, which trait for each pea characteristic is dominant? In your science notebook make a table like the one below. In your table, list the dominant and recessive traits for each characteristic.

	Characteristic	Dominant Trait	Recessive Trait	Ratio Dominant:Recessive
	Flower color			
	seed color			
	seed surface			
	pod color			

2.
 - a. Calculate to the hundredths place the ratio of dominant to recessive for each characteristic in the third generation. Record the ratio for each characteristic in the table you prepared for Question 1.
 - b. Why are the ratios not exactly 3:1?
3. Look at the pie chart on the previous page, which shows the ratio of green-seeded and yellow-seeded offspring. Explain why a 1:3 ratio of green-seeded plants to yellow-seeded plants is the same as a fraction of $\frac{1}{4}$ green-seeded plants.
4. Mendel performed his experiments on more characteristics than the four shown in Figure 1. Why was it important for him to look at more than one characteristic?
5. **Reflection:** People often think of mathematics as important to physics and chemistry, but not to life science (biology). What is your opinion?